Ozone, a gas present throughout the Earth's atmosphere, is a pollutant at the Earth's surface but forms a protective layer in the stratosphere, helping shield the Earth from the sun's ultraviolet (UV) radiation. Exposure to UV rays is associated with skin cancer, cataracts, and other human health and ecological problems (U.S. EPA, 2006).

Starting in the late 1970s, stratospheric ozone levels were observed to be declining due to worldwide releases of various human-produced chemicals referred to as ozone-depleting substances (ODSs), particularly halocarbons such as the long-lived chlorofluorocarbons (CFCs), bromine-containing halons, and methyl bromide. Through rapid catalytic reactions with ozone, the chlorine and bromine from these chemicals have depleted the protective ozone layer (the Ozone Levels over North America indicator).

Worldwide production and consumption of ODSs is being progressively eliminated under the provisions of the 1987 Montreal Protocol on Substances That Deplete the Ozone Layer. Over time, reducing the atmospheric loading of ODSs is expected to result in global increases in stratospheric ozone. However, because some ODS gases have long atmospheric lifetimes, and because of pre-phaseout ODS stockpiling for post-phaseout use, ambient concentrations of ODSs have only recently begun to stabilize and in some cases begun to decline. While some gases, like methyl chloroform, decay quickly in the atmosphere, other gases, like CFCs and halons, have atmospheric lifetimes on the order of hundreds or thousands of years.

Measures of effective equivalent troposphere chlorine (EECl) and effective equivalent stratospheric chlorine (EESC) are commonly used to represent atmospheric concentrations of ODSs. Both represent ODS concentrations weighted by their potential to catalyze the destruction of stratospheric ozone relative to the ability of chlorine to do so. (EESC is typically derived by adding a 3-year time lag to EECl to account for the time it takes for emissions of ODSs at the Earth's surface to migrate from the troposphere to the stratosphere and cause stratospheric ozone depletion.)

This indicator presents trends in concentrations of tropospheric ODSs as EECl. The EECl trend is based on measurements from the National Oceanic and Atmospheric Association (NOAA) Climate Monitoring and Diagnostics Laboratory and estimates of halocarbon emissions from industrial and international sources from 1995 to 2007. Concentrations of EECl are presented as weighted averages based on ground-based measurements of mixing ratios[1] since 1995 at the following remote locations: Alert, Northwest Territories, Canada; Barrow, Alaska; Niwot Ridge, Colorado; Mauna Loa, Hawaii; American Samoa; Cape Grim, Tasmania, Australia; and the South Pole (NOAA CMDL, 2003). Data on total EECl are also available for 1992 through 1994, but these years of monitoring

[1] The mixing ratio is the ratio of the partial pressure of a gas to the total atmospheric pressure.

Exhibit 2-44. Global effective equivalent chlorine concentrations, 1995-2007[a]
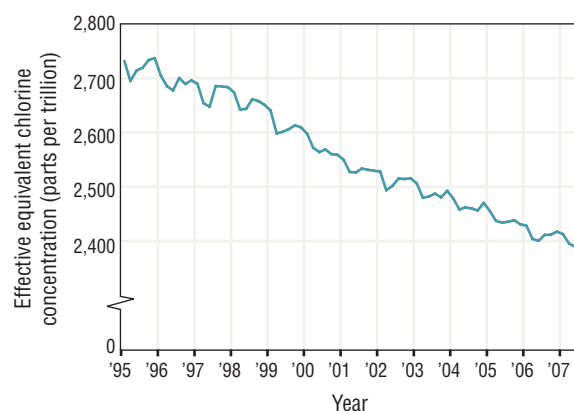
[a]Effective equivalent chlorine (EECl) is typically used to represent atmospheric concentrations of ozone-depleting substances. The EECl reflects contributions from multiple ozone-depleting substances, weighted by their potential to catalyze the destruction of stratospheric ozone.

Data source: NOAA, 2008

are only presented in the chemical-specific graphs because the monitoring did not include methyl bromide, a quantitatively important ODS. Because most ODSs have long atmospheric half-lives, the ODS concentrations shown in this indicator reflect past and recent contributions from emissions sources within the U.S. and worldwide.

What the Data Show

Total EECl resulting from ODS emissions reached its peak concentration in the mid-1990s at slightly over 2,700 parts per trillion of air by volume and has declined by approximately 13 percent since then (Exhibit 2-44). Although tropospheric concentrations of CFCs and several other individual ODS compounds have begun to decline, concentrations of halons and selected hydrochlorofluorocarbons (HCFCs) have not yet stabilized.

Declines in EECl abundances of several ODSs in the troposphere between 1992 and 2007 have contributed to the decline in total EECl (Exhibit 2-45). EECl attributed to methyl chloroform has decreased by nearly 91 percent over this period due to decreased emissions as well as its short atmospheric lifetime. EECl associated with CFCs has decreased more slowly: 2007 levels are approximately 5 percent lower than the peak tropospheric concentration that occurred between 1995 and 1997. The slow decay of CFCs is a result of continued emissions of CFCs from stockpiles in developed countries, continued use in developing countries, and their longer atmospheric lifetimes. EECl from methyl bromide has decreased nearly 22 percent from its peak in

1998; however, continued use of methyl bromide in developing countries and in developed countries through critical use exemptions slows the decrease in EECl associated with this compound. EECl from methyl bromide exhibits seasonal variations, which likely results from the seasonal use of this chemical as a soil fumigant.

Although some tropospheric ODSs have declined in concentration, others, including halons and HCFCs, continue to increase (Exhibit 2-45). EECl estimated from halon emissions has increased by 53 percent from 1992 to 2007, and EECl attributed to HCFCs in 2007 is 2.8 times higher than that from 1992. These trends reflect continued emissions of these ODSs from stockpiles in developed countries and continued production and consumption in developing countries (and developed countries for HCFCs), as well as the longer atmospheric lifetimes of halons.

Indicator Limitations

- The calculation of EECl depends on the understanding of the interactions and atmospheric residence times of many different gases; incorrect knowledge about these factors could affect trends in the EECl.

- EECl is calculated by weighting each ODS's concentration by the substance's ability to catalyze destruction of stratospheric ozone, or the ozone destruction potential. The ozone destruction potentials used to transform the data have inherent uncertainties, which can affect the trend analyses.

- Factors additional to trends in halocarbons affect trends in stratospheric ozone. These factors include changes in climate (e.g., temperature, winds), changes in emissions and concentrations of trace gases like nitrous oxide and methane, and changes in aerosol loading such as occurs after an explosive volcanic eruption.

Data Sources

Tropospheric concentrations of ODSs presented in this indicator are based on measurements made by NOAA's Global Monitoring Division and summarized at an online data repository (NOAA, 2008) (ftp://ftp.cmdl.noaa.gov/hats/Total_Cl_Br/). The trend in this indicator was developed from a data file available from the repository ("2008b update"), which updates tropospheric ODS concentrations previously reported in the peer-reviewed literature (Montzka et al., 1999, 2003).

References

Montzka, S.A., J.H. Butler, B.D. Hall, D.J. Mondeel, and J.W. Elkins. 2003. A decline in tropospheric organic bromine. Geophys. Res. Lett. 30(15):1826.

Exhibit 2-45. Global effective equivalent chlorine concentrations of selected ozone-depleting substances, 1992-2007[a]
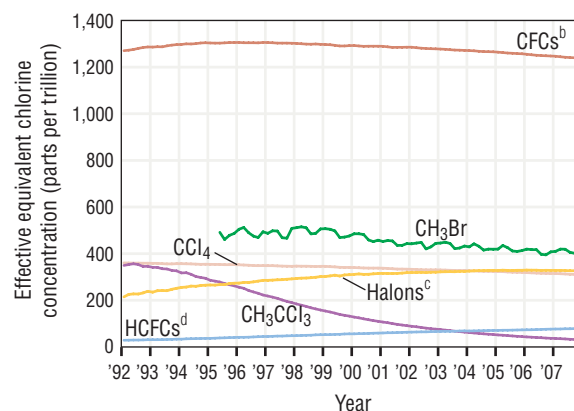
[a]Effective equivalent chlorine (EECl) is typically used to represent atmospheric concentrations of ozone-depleting substances. The EECl of ozone-depleting substances is calculated from the substances' atmospheric concentrations and their potential to catalyze the destruction of stratospheric ozone.

[b]The chlorofluorocarbons (CFCs) considered in this figure are CFC-11, CFC-12, and CFC-113.

[c]The halons considered in this figure are halon 1211 and halon 1301.

[d]The hydrochlorofluorocarbons (HCFCs) considered in this figure are HCFC-22, HCFC-141b, and HCFC-142b.

Data source: NOAA, 2008

Montzka, S.A., J.H. Butler, J.W. Elkins, T.M. Thompson, A.D. Clarke, and L.T. Lock. 1999. Present and future trends in the atmospheric burden of ozone–depleting halogens. Nature 398(6729):690–694.

NOAA (National Oceanic and Atmospheric Administration). 2008. Online repository of global tropospheric mixing ratios of ozone–depleting gases. Accessed 2008. <ftp://ftp.cmdl.noaa.gov/hats/Total_Cl_Br/>

NOAA CMDL (National Oceanic and Atmospheric Administration, Climate Monitoring and Diagnostics Laboratory). 2003. Summary report no. 27. Boulder, CO. <http://www.cmdl.noaa.gov/publications/annrpt27/>

U.S. EPA (United States Environmental Protection Agency). 2006. Air quality criteria for ozone and related photochemical oxidants. EPA/600/R–05/004aF–cF. Research Triangle Park, NC. <http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=149923>